

Body Fatness and Risk for Elevated Blood Pressure, Total Cholesterol, and Serum Lipoprotein Ratios in Children and Adolescents

ABSTRACT

Background. Recent studies have shown considerable variation in body fatness among children and adolescents defined as obese by a percentile rank for skinfold thickness.

Methods. We examined the relationship between percent body fat and risk for elevated blood pressure, serum total cholesterol, and serum lipoprotein ratios in a biracial sample of 3320 children and adolescents aged 5 to 18 years. Equations developed specifically for children using the sum of subscapular (S) and triceps (T) skinfolds were used to estimate percent fat. The S/T ratio provided an index of trunkal fat patterning.

Results. Significant overrepresentation (>20%) of the uppermost quintile (UQ) for cardiovascular disease (CVD) risk factors was evident at or above 25% fat in males (32.2% to 37.3% in UQ) and at or above 30% fat in females (26.6% to 45.4% in UQ), even after adjusting for age, race, fasting status, and trunkal fat patterning.

Conclusions. These data support the concept of body fatness standards in White and Black children and adolescents as significant predictors of CVD risk factors. Potential applications of these obesity standards include epidemiologic surveys, pediatric health screenings, and youth fitness tests. (*Am J Public Health*. 1992;82:358-363)

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Introduction

The association between skin-fold thicknesses in children and adolescents and elevated levels of variables considered to be indicative of risk for cardiovascular disease (CVD) in adults has been found by several investigators.¹⁻⁵ In population-based studies of children and adolescents, for example, excess subcutaneous fatness has been associated with elevated blood pressure (BP),^{1,2,6} serum lipids, and lipoprotein fractions,²⁻⁴ and the clustering of these variables.⁵ Although the results of these studies demonstrate that elevated levels of CVD risk factors often accompany excess body fat in youth, the absolute level of body fat corresponding to significant risk for high BP, serum lipids, low-density lipoprotein (LDL) and very low-density lipoprotein (VLDL) cholesterol is not known.

Although children and youth with triceps skinfolds \geq the 85th percentile for age and sex are at greater risk for high BP than children with lower skinfold thicknesses,¹ such a rank-ordered definition of obesity implies that the absolute level of body fatness associated with increased risk is variable. Recent work has shown that the 85th percentile may not be indicative of obesity in all samples, because skinfold thicknesses at a given percentile correspond to different levels of body fat at different ages.^{7,8} The 85th skinfold percentile, for example, represents fatness levels ranging from 17% to 22% in children and from 25% to 34% in adolescents.⁸

In addition to the discrepancy between relative and absolute definitions of obesity, the triceps skinfold site has been shown to be unrelated to BP in youth when statistical adjustments were made

for subscapular skinfold thickness.⁹ Moreover, a trunkal fat pattern, independent of general body fatness, is related to high levels of LDL and VLDL and to low levels of high-density lipoprotein (HDL) cholesterol in 6- to 18-year-old youth.¹⁰ The independent effects of centripetal localization of subcutaneous fat on BP^{9,11} and adverse lipoprotein profiles¹⁰ make it important to control the potential confounding effect of fat patterning when the relation between total body fat and CVD risk factors in youth is evaluated.

The purpose of the present study was to determine the level of body fatness, independent of fat patterning, associated with significant risk for elevated BP, total cholesterol, and serum lipoprotein ratios in a biracial sample of children and adolescents aged 5 to 18 years. The aim was to develop cardiovascular health-related percent body fat standards that may be applied to epidemiologic investigations of the prevalence and incidence of obesity in children and adolescents, pediatric health screenings, and national youth fitness tests.^{12,13}

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Methods

Study Sample

The sample included 1667 males (1062 White, 605 Black) and 1653 females (1028 White, 625 Black) aged 5 to 18 years. All subjects were residents of Ward 4, Washington Parish, La, and were participants in the Bogalusa Heart Study. The data were collected in the years 1983 through 1985. An extensive review of the demographic characteristics of this biracial community, as well as the overall design of this large, population-based investigation of children and youth, has been published elsewhere.¹⁴ The Louisiana State University Medical Center reviews experiments related to human subjects. Written informed consent was obtained from a parent or guardian of each child.

Procedures

Total body fat and fat distribution.

Total body and regional fatness were estimated from limb (triceps) and trunk (subscapular) skinfold thicknesses. Lange calipers were used to measure triceps and subscapular skinfolds to the nearest 1.0 mm. Skinfold measurement technique and site location have been described previously.^{14,15} The reliability of these measurements, assessed by test-retest intraclass correlations, was of equal magnitude ($r = 0.98$) for both sites.¹⁶

Body density (D_b) was estimated from age and the sum of triceps and subscapular skinfolds (STSS) and was subsequently used to derive total percent body fat. The STSS-to- D_b conversion was based on race- and gender-specific regression equations that were derived from the pooled skinfold and body density data from several samples of White and Black youth measured in different laboratories (Appendix).¹⁷⁻²⁰ We then used a modification of the density-to-percent-fat conversion constants reported by Lohman²¹ to convert D_b to percent body fat (Table 1, Eqs. 1 and 2). These youth-specific constants adjust for growth- and maturation-related differences in fat-free body density (D_{FFB}) at different ages and prevent the systematic overestimation of body fat when adult density-to-percent-fat equations are applied to chemically immature children and youth.²² The present combination of equations was chosen over other multicomponent-based equations for youth that convert STSS directly to percent fat²³ because the multilaboratory equations used herein may be more generalizable.

TABLE 1—Multilaboratory-based Estimation of Body Density from the Sum of Triceps and Subscapular Skinfolds (STSS) and Age in White and Black Children and Adolescents^a

Variable	Males		Females	
	White (n = 262)	Black (n = 96)	White (n = 219)	Black (n = 94)
STSS (mm)	-0.00227	-0.00203	-0.00188	-0.00162
STSS ² (mm ²)	0.000015	0.000012	0.000013	0.000008
Age, yr	0.00243	0.00193	0.00191	0.00165
Intercept	1.0600	1.0682	1.0533	1.0580
Adjusted intercept		1.0666		1.0555
R ²	0.70	0.65	0.58	0.70
SEE (g/cm ³)	0.0102	0.0107	0.0096	0.0089

^aBecause currently available equations for converting body density (D_b) to percent fat²¹ are based more on the fat-free body composition of Whites than of Blacks, we adjusted the intercepts in the above equations for Black males and females to remove the influence of differences in fat-free body density (D_{FFB}) on D_b and, subsequently, on estimates of body fat. Body density was converted to body fat using age-adjusted, gender-specific equations derived by regression analysis from age and the recently reported age-specific body density constants,²¹ thereby deriving the following equations to estimate percent fat (PF) from D_b :

- (1) $PF_{\text{males}} = [(5.68 - (0.041 \times \text{age})) \div D_b] - [(5.31 - (0.045 \times \text{age}))] \times 100$
 (2) $PF_{\text{females}} = [(5.69 - (0.038 \times \text{age})) \div D_b] - [(5.31 - (0.041 \times \text{age}))] \times 100$

To determine the critical level of body fat associated with elevated CVD risk factor variables, the males and females were subsequently grouped by level of percent fat. Males were divided into the following five fatness groups: <10% (n = 217), 10% to 14.9% (n = 575), 15% to 19.9% (n = 436), 20% to 24.9% (n = 192), and $\geq 25\%$ (n = 247). Females were grouped by body fat as follows: <20% (n = 547), 20% to 24.9% (n = 493), 25% to 29.9% (n = 313), 30% to 34.9% (n = 192), and $\geq 35\%$ (n = 108).

An index of trunk-to-limb fat distribution was computed as the natural logarithm of the subscapular/triceps skinfold thickness ratio.²⁴ Because absolute standards for children and youth do not exist for this index of fat patterning, age-, sex- and race-specific percentiles for the present sample were developed. Fat-patterning quintile, used as a covariate of percent fat in this report, refers to the contrast of youth in the uppermost quintile for \log_n (subscapular/triceps) with those in the lower four quintiles. This contrast was used in the analysis to control for the potential confounding effect of trunkal fatness in assessing the relation of total body fat with BP⁹ and serum lipoproteins.¹⁰

CVD risk factor variables. The protocol, standardization, and training of observers used to measure BP¹⁴ and the blood collections required to assess serum total cholesterol and lipoprotein levels³ have previously been outlined in detail. Seated, resting BP measures on the right arm were made in triplicate with a mercury sphygmomanometer by trained

nurses; the mean of six readings at the first (systolic) and fourth (diastolic) Korotkoff sounds was used in the data analysis. In an earlier Bogalusa Heart Study survey, reliability coefficients ranged from $r = .84$ to $r = .86$ for systolic BP and from $r = .76$ to $r = .78$ for diastolic BP.¹⁶

Serum total cholesterol and lipoproteins were measured at Louisiana State University Core Lipid Laboratory, New Orleans, La, which has been standardized by the Centers for Disease Control in Atlanta, Ga. Laboratory measurement quality is routinely monitored by a surveillance program. Serum total cholesterol concentration was measured with an AutoAnalyzer II, according to the recommendations of the Lipid Research Clinics.²⁵ A combination of heparin-calcium precipitation and agar-agarose gel electrophoresis²⁶ was used to determine the levels of lipoprotein cholesterol fractions (VLDL-C, LDL-C, and HDL-C). Reliability coefficients (intraclass correlations) ranging from $r = .89$ to $r = .97$ were reported earlier for these variables.¹⁶

For the purpose of this report, elevated BP, total cholesterol, and lipoprotein cholesterol were individually defined as levels in the uppermost quintile of the age-, race-, and sex-specific distributions for systolic BP, diastolic BP, total cholesterol, the LDL-C/HDL-C ratio, and the ratio of VLDL-C + LDL-C/HDL-C. The uppermost quintile was chosen to define elevated CVD risk factor variables because an earlier study²⁷ demonstrated this cutoff point to be a more sensitive indica-

TABLE 2—Sample Size and Percentage of Subjects in the Fifth Quintile (Q5) for Blood Pressure, Total Cholesterol, and Serum Lipoprotein Ratios at Increasing Levels of Body Fat

% Fat	SBP ^a			DBP ^b			TCHOL ^c			LR-1 ^d			LR-2 ^e		
	No. Q1–5	No. Q5	% Q5	No. Q1–5	No. Q5	% Q5	No. Q1–5	No. Q5	% Q5	No. Q1–5	No. Q5	% Q5	No. Q1–5	No. Q5	% Q5
Males															
<10.0	217	17	7.8*	217	26	12.0*	213	39	18.3	213	37	17.4	213	34	16.0
10.0–14.9	575	99	17.2*	573	87	15.2*	570	91	16.0*	566	89	15.7*	566	84	14.8*
15.0–19.9	436	85	19.5	436	82	18.8	432	83	19.2	432	80	18.5	432	78	18.1
20.0–24.9	192	40	20.8	192	47	24.5**	191	39	20.4	191	33	17.3	191	34	17.8
≥25.0	247	86	34.8**	247	86	34.8**	236	76	32.2**	228	82	36.0**	228	85	37.3**
Females															
<20.0	547	68	12.4*	547	66	12.1*	538	88	16.4*	537	77	14.3*	537	80	14.9*
20.0–24.9	493	87	17.6*	493	85	17.2*	481	78	16.2*	478	82	17.2*	478	83	17.4*
25.0–29.9	313	75	24.0	313	73	23.3	308	72	23.4	308	52	16.9	308	54	17.5
30.0–34.9	192	51	26.6**	192	61	31.8**	187	54	28.9**	187	61	32.6**	187	62	33.2**
≥35.0	108	49	45.4**	108	40	37.0**	100	31	31.0**	99	35	35.4**	99	37	37.4**

^aSBP = systolic BP.^bDBP = diastolic BP.^cTCHOL = total cholesterol.^dLR-1 = LDL-C/HDL-C.^eLR-2 = (VLDL-C + LDL-C)/HDL-C.*significantly less than that expected by chance, $P < .05$.**significantly greater than that expected by chance, $P < .05$.

tor of future high BP than was the more stringent 95th percentile.

Data analysis. A chi-square test was used to determine whether the percentages of subjects in the fifth quintile for BP, total cholesterol, and lipoprotein ratios were significantly different than those expected by chance alone (20%) at each level of body fatness in both sexes. Logistic regression analysis²⁸ was used to estimate the relative odds for elevated BP, total cholesterol, and lipoprotein ratios between contrasting percent fat groups of interest, while holding potential confounders constant. Presence or absence of elevated BP, total cholesterol, and lipoprotein ratios were the dependent variables in the logistic regression analyses. The independent variables included several percent fat group contrasts; a contrast for fat-patterning quintile; race; age; and, for the total cholesterol and lipoprotein ratio analyses, fasting status. The risk for membership in the uppermost quintile for the cardiovascular variables was defined as 1.00 in the lowest percent fat group. The odds of uppermost quintile membership were thus determined for each of the upper four percent fat groups relative to the leanest group within each gender.

Results

The unadjusted bivariate relationships between body fat and CVD risk factor variables is shown in Table 1. A dose-response effect was observed between BP

and percent body fat; in contrast, total cholesterol and the lipoprotein ratios were relatively independent of percent body fat among the lower four fatness groups in males and the lower three fatness groups in females (Table 2). The percentage of subjects in the uppermost quintile for all CVD risk factor variables was significantly ($P < .05$) greater than that expected by chance alone (20%) in males with ≥25% fat and in females with ≥30% fat. The ≥35% fat group of females displayed even greater overrepresentation (31.0% to 45.4% vs 26.6% to 33.2%) in the uppermost quintile than did the 30% to 34.9% fat group of females.

Multivariate-based estimates of the relative odds for elevated BP, total cholesterol, and lipoprotein ratios, adjusted for potential confounding variables at increasing levels of percent body fat, are presented in Figure 1 for males and Figure 2 for females. After accounting for potential confounding by age, race, trunkal fat patterning, and fasting status, males with body fat ≥25.0% were 2.8 (1.7–4.8) to 7.0 (3.6–13.6) times as likely as those in the leanest group (<10% fat) to have elevated systolic BP, diastolic BP, LDL-C/HDL-C ratios, and VLDL-C + LDL-C/HDL ratios (Figure 1). In females, the 30% to 34.9% fat group was 2.7 (1.6–4.5) to 3.8 (2.3–6.1) times more likely than the leanest group (<20% fat) to be in the uppermost quintile for these CVD risk factor variables; the likelihood for elevated BP and lipoprotein ratios in the female

≥35.0% fat group ranged from 3.3 (1.8–5.9) to 4.9 (2.8–8.7) (Figure 2).

Discussion

This study is unique because critical levels of body fat, as opposed to skinfold thickness percentile, that correspond to significant risk for elevated BP and lipoprotein ratios were determined and found to be independent of trunkal fat patterning in a biracial sample of children and youth. Inherent in previous normative value-derived definitions of childhood obesity¹ is the considerable age-related variation in body fatness at a constant percentile for skinfold thickness.^{7,8} This concept is supported by the finding that the 85th percentile for the STSS in the present sample of children and adolescents represents body fatness values ranging from 14.8% to 34.3% fat in males and from 21.9% to 37.7% fat in females. Moreover, the finding that critical levels of body fatness were related to elevated levels of CVD risk factor variables independent of trunkal fat patterning is particularly relevant in light of recent studies^{5,10,29} establishing the link between trunk fatness and high levels of BP, serum lipoprotein fractions, and serum insulin in children and adolescents. The independent relationships of CVD risk factors with percent body fat in children and adolescents and with trunkal fat patterning in adolescents³⁰ suggest that measurement of both total and regional

fatness may be informative, especially for adolescent health screenings.

The magnitude and statistical significance of the odds for uppermost quintile membership at increasing levels of body fat, relative to the leanest group, were somewhat greater for the BP variables than for the lipoprotein variables (Figures 1 and 2). This difference in adjusted odds ratios between the BP variables and lipoprotein ratio variables may best be explained by differences in uppermost quintile membership rates within the leanest reference groups (<10% fat, males; <20% fat, females). In males, for example, for whom the difference in odds ratios between the BP variables and lipoprotein ratio variables at each level of body fat was most evident, the reference body-fat group was significantly protected against elevated BP but not against elevated lipoprotein ratios (Table 2). The trend observed in males—for the lowest risk for elevated lipoprotein ratios to occur in the 10% to 14.9% fat group—somewhat parallels the trend for higher mortality rates in the lowest-weight-for-height group than in the middle-weight-for-height group observed in adult participants of the Framingham Study.³¹ However, none of the middle percent-fat groups was significantly more protected against elevated total cholesterol or lipoprotein ratios than was the leanest group (Figure 1).

In an analysis of national survey data, 6- to 11-year-old children with triceps skinfold thicknesses at or above the 85th percentile were found to be 2.6 and 1.6 times as likely as their leaner peers to have elevated systolic BP and diastolic BP, respectively.¹ Similarly, in 12- to 17-year-old youth, the risks for elevated systolic BP and diastolic BP were 4.3 and 6.1 times higher, respectively in youth having skinfold thicknesses equal to or exceeding the 85th percentile. Although the odds ratio estimates from the present study compare reasonably well with those reported previously for adolescents, they are somewhat higher than those reported for children.¹

Several differences between the present study and the national survey analysis may account for the discrepancies in the reported relationships between body fatness and elevated BP. The 85th percentile for triceps skinfold thickness was used as an index of body fat in the previous study,¹ whereas in the present study, percent body fat was estimated from the STSS. Also, the previous study¹ referenced youth of both sexes with skinfold thicknesses equal to or exceeding the 85th percentile against those with skinfold

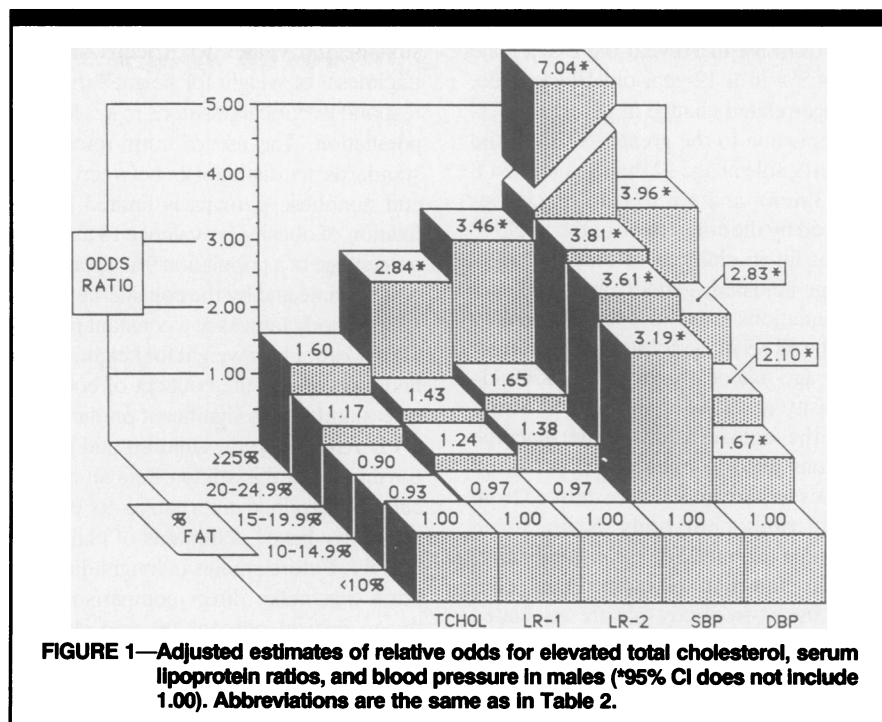


FIGURE 1—Adjusted estimates of relative odds for elevated total cholesterol, serum lipoprotein ratios, and blood pressure in males (*95% CI does not include 1.00). Abbreviations are the same as in Table 2.

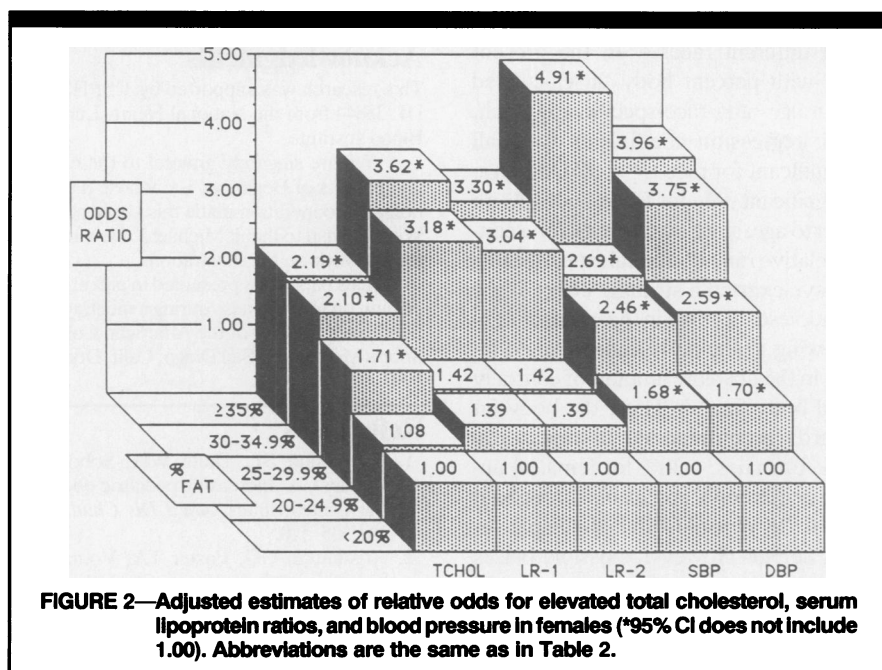


FIGURE 2—Adjusted estimates of relative odds for elevated total cholesterol, serum lipoprotein ratios, and blood pressure in females (*95% CI does not include 1.00). Abbreviations are the same as in Table 2.

thicknesses below the 85th percentile; however, in the present study, we contrasted four separate gender-specific percent fat groups at 5% intervals against the leanest males (<10% fat) and females (<20% fat), as appropriate. In addition, elevated BP was defined with a more stringent cutoff point (≥95th percentile) in the previous study¹ than was used in this study (≥80th percentile). Finally, in the present study, potential confounding by fat patterning was statistically controlled

by using a contrast for the quintile level of log_n (subscapular/triceps); seasonality, but not fat pattern, was controlled in the previous investigation.¹

Because a relative index of body fatness corresponding to the 85th percentile for triceps skinfold thickness was used in the earlier study,¹ it is not surprising that substantially lower estimates of risk were observed in the younger children than in the adolescents. In the present study, for example, the STSS corresponding to the

85th percentile results in percent-fat estimates of 14.8% in a 6-year-old Black male and 34.3% in a 12-year-old Black male. This age-related change in percent-fat estimates is due to the greater STSS at the 85th percentile at age 12 than at age 6 (54.8 vs 17.3 mm), and not to inaccuracies introduced by the conversion of the STSS to percent fat in children of different ages. The age-adjusted, gender- and race-specific equations used to estimate density from the STSS in the present study correct for the age-related change in the skinfold-to-density relationship in youth.²² Moreover, the age-adjusted gender-specific equations used to convert the predicted densities to percent fat were derived from a multicomponent body composition model that accounts for age-related differences in the water and bone mineral content of the fat-free body that are associated with growth and development.^{21,22}

Individual skinfold thicknesses may be inaccurate indicators of body fatness, inasmuch as a constant skin-fold thickness corresponds to a different body density and percent body fat at different ages²² and in different races.²³ In the present study, with percent body fat calculated with an age- and race-specific approach, logistic regression coefficients were all nonsignificant for race ($P > .05$), and age was significant only for BP in males. With respect to age, statistical control for a constant relative rank of trunkal fat patterning may have exerted a stronger effect in the older adolescents than in the younger children owing to the pubescence-related increase in the absolute amount of centrally located body fat.^{24,30} Thus, the body fat standards recommended in this study ($\geq 25\%$ for males, $\geq 30\%$ for females) appear to be generally applicable throughout the 5- to 18-year-old biracial sample reported herein. However, possible biases due to subject selection, nonresponse, and geographic location may limit the generalizability of these standards, and point to the need for further validation of these standards in national probability-based samples.

On the basis of the present findings, we conclude that fatness levels at or above 25% in males and 30% in females are indicative of increased risk for elevated BP and lipoprotein ratios in White and Black children and adolescents. These new body fatness standards are applicable not only to epidemiologic studies of the prevalence and incidence of obesity in children and adolescents, but also to pediatric health screenings and health-related tests of youth fitness.^{12,13} Previous studies have

defined childhood obesity with age- and sex-specific values for triceps skinfold thickness¹ or weight for height³² that correspond to critical positions in a reference population. The use of norm-referenced standards to distinguish between obese and nonobese persons is limited by the fixation of obesity prevalence to a certain percentage of a population³³ at a particular point in time and by the considerable variation in body fatness at a constant percentile of skinfolds or weight for height.^{7,8} Our findings support the concept of body fatness standards as significant predictors of CVD risk factors in children and youth. Furthermore, this study offers an empirically determined alternative to current normative-based definitions of childhood obesity. Future studies in longitudinal cohorts that make direct comparisons between critical percent fat and skinfold thickness percentile cutoff points are needed to assess the specificity and sensitivity of the two screening tools. □

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Deadline for Student Papers on Injury Is March 31, 1992

The Southern California Injury Prevention Research Center is pleased to announce a competition for the best student papers in 1991 on injury. Papers must focus on public health aspects of intentional injury (homicide, suicide, sexual assault, battering, child abuse, etc.) or unintentional injury (motor vehicle crashes, falls, drowning, burns, etc.). Priority will be given to original scientific contributions that focus on injuries in ethnic or racial minorities, the poor, and other traditionally underserved populations.

Three awards are anticipated in the amounts of \$500, \$250, \$150 for manuscripts that demonstrate original methods in injury research, analyze new data, or emphasize findings with countermeasure potential. The award will be made directly to the student in recognition of his or her contribution to injury research.

Although papers published in 1991 will be considered, the submission of unpublished manuscripts is strongly encouraged. Papers should be submitted by the student or by an academic adviser on behalf of the student and with his or her permission. If unpublished, the manuscript (including refer-

ences and tables) should not exceed 30 double-spaced pages. In addition to the manuscript, a letter from the student's adviser should be submitted which verifies that the work and writing were conducted by the student who was enrolled in graduate training during 1991. Full acknowledgment of the student's primary role in the work should be reflected through his or her first authorship of the paper. All submissions must include student's name, address, and daytime telephone number. Manuscripts should be prepared according to the *American Journal of Public Health* style guidelines and submitted in triplicate to Jess F. Kraus, PhD, Southern California Injury Prevention Research Center, UCLA School of Public Health, 10833 Le Conte Avenue, Los Angeles, CA 90024-1772. The deadline for submissions, which was omitted from the previous announcement in the January issue of the *American Journal of Public Health*, is March 31, 1992.

Inquiries may be directed to Renee Goetz, MSW, Administrative Coordinator, at the same UCLA address (telephone 213/206-4115).